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Improvement Of Production System Efficiency and Production Capacity Using Line Balancing Method

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Abstract— This study discusses the research results conducted on an Indonesian plastic manufacturing company. The distribution of the workload in a production process needs to be calculated so that the company is able to achieve the target of production. This research was conducted to improve the efficiency of production systems and the production capacity of the company so that the company is able to meet production targets. The method used in this study is line balancing. Time study method is conducted to calculate cycle time and then forecasting method is utilized to determine production target and required cycle time. After that, 3 methods of line balancing: ranked positional weights, Moodie Young and new bidirectional is used. The result of the line balancing method shows that the best methods are Moodie Young and new bidirectional with the efficiency of 82.97%, much higher from the current state, which is only 48.89%. The number of workstation is also decreased from 9 to 7. The production also increased from 780.41 pieces per day to 1,030.07 pieces per day.

Keywords— line balancing; ranked positional weight, Moodie & Young; New Bidirectional method; plastic manufacturing

I. INTRODUCTION

In this globalization era, many changes and developments that occurred changed the mindset and forcing companies to be more advanced. Therefore it is important for the company to provide the best product or service to the consumer so that the company can compete in the market.

Operations management is a set of activities that produce value in the form of goods or services by transforming inputs into outputs [1]. If the division of the workload of each work station is different, so the production process can be interrupted.

Method that can be used to balance the production line is the line balancing. Line balancing is a technique to spread the load of work in all processes in the cell or value stream to remove bottlenecks [2]. An Indonesian plastic manufacturing company is facing problems in its plastic bag production line. Fig. 1. shows that the company still difficult to meet production targets, where the amount of production per month is always lower than the production target should be. Non-

fulfillment of production targets is because there is a division of the workload that is not balanced in each work station.

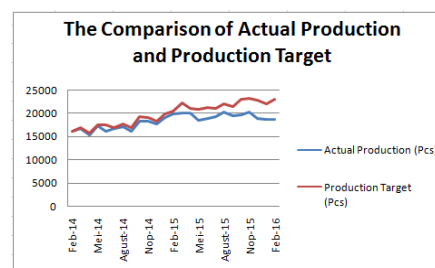


Fig. 1. Comparison of Actual Production and Production Target

The condition forces the company to add overtime to meet production targets. This ultimately makes the company overtime hours increased and exceeded the company's policy that only allows a maximum of 2 hours.

The company needs to balance the line to make its line more efficient.

II. LITERATURE STUDY

A. Time Study

The cycle time (cycle time) is the period of time required to complete an operation. Calculation of the cycle time can use the following formula [3]:

$$C = \frac{T}{N} \quad (1)$$

Where:

C = Cycle Time; T = Production time per day; N = Total Production per day

Normal time can be calculated using this formula [4]:

$$\text{Normal Time} = \text{Cycle Time} \times \frac{\% \text{ Performance}}{100\%} \quad (2)$$

The standard time is the overall time required by a worker or operator who has average ability to complete a job. Standard time can be calculated using this formula [4]:

$$\text{Standard Time} = \text{normal time} \times \frac{100\%}{100\% - \% \text{ allowance}} \quad (3)$$

To determine the normal distribution of data, Kolmogorov-Smirnov test was used. If the value of the data significance is greater than the error level, which usually is 5% then the data is normal [5].

To conduct uniformity test, Upper control limit (UCL) and lower control limit (LCL) is calculated by using the following formula [4]:

$$\text{UCL} = \text{Mean} + 3 \text{ Standard Deviation} \quad (4)$$

$$\text{LCL} = \text{Mean} - 3 \text{ Standard Deviation} \quad (5)$$

Test adequacy observation data needs to be done in order to know whether the data that have been taken have been sufficient. The formula for calculating the data adequacy test are as follows [4]:

$$N' = \left(\frac{\frac{k}{s} \sqrt{N \sum X_i^2 - (\sum X_i)^2}}{(\sum X_i)} \right) \quad (6)$$

Where:

N' = Number of observations / observations should be made

N = number of observations that have been made

X_i = Data element i

K = Confidence level = 95%, $k = 2$

S = Level of accuracy = 5% = 0.05

If $N' < N$ then data are adequate.

B. Line Balancing

The efficiency of the line is the calculation of the efficiency of the existing work time as a result of the line balancing. Can be calculated using the formula [3]:

$$\text{HE} = \frac{T}{N.C} \times 100\% \quad (7)$$

Where:

HE = Line Efficiency; N = Total work station; C = cycle time;

T = Work time per day

Smoothing index is an index that describes the smoothness of line balancing. The minimum value is 0. The following formula is used [6]:

$$\text{SI} = \sqrt{\sum_{i=1}^N (\text{ST}_{\max} - \text{ST}_i)^2} \quad (8)$$

Where:

ST_{\max} = Maximum time of work stations

ST_i = Minimum time of work station

Balance delay is the calculation of inefficiencies caused by the imperfection of work allocation between work stations [7]:

$$\text{BD} = \frac{N.T_c - \sum \text{Tei}}{N.T_c} \times 100\% \quad (9)$$

Where:

BD = Balance delay; Tei = Total time in production line; N =

Total work station; T_c = Maximum Cycle Time

Line balancing methods:

1. Rangked Positional Weights (RPW)

RPW method can be explained as follows [8]:

1. Calculate the desired speed.
2. Create a preliminary matrix based on network assembly work
3. Calculate the weight of each operation based on the amount of time the operation and the operations that followed.
4. Sort operations ranging from the position of greatest weight to the weight of the smallest position.
5. Place operations at the work station with weights ranging from the largest position until the weight of the smallest position with the criteria that total operating time is smaller than the given track speed.
6. Calculate the average efficiency of the work stations are formed
7. Use trial and error procedure to seek the imposition of which would produce an average efficiency greater than average efficiency at the point 6 above.
8. Repeat step 6 and 7

2. Moodie Young

Moodie Young method has two phases [9]:

The first phase:

Make grouping work stations. Working elements placed at the work station with the rules, if there are two elements of work that could have the elements of work that has a larger time placed first. In this phase also, from the precedence diagram created matrix P and F , which describes the work element precursor (P) and the elements of work that follow (F) for all elements of the existing work.

The second phase:

1. The identification of a work station and a work station the smallest.
2. Calculate $GOAL = (Max\ Cycle\ Time - Min\ Cycle\ Time)/2$
3. Identification of a working element contained in the work station with the maximum time, which has a smaller time than GOAL, move that element if when it was moved to the work station, it does not violate the precedence diagram.
4. Move the working elements.
5. Repeat until no more evaluation elements of work that can be moved

3. New Bidirectional

New Bidirectional method consists of four steps [10]:

1. Determining the critical path, then separate the elements of work that is in the critical path (S_{cp}) and which are not (S'_{cp})
2. Creating a temporary work station (FS and BS)
3. Allocate element of the critical path that has no predecessor to the FS and which does not have followers to BS, allocate elements not to exceed the cycle time.
4. Calculate the value W_f and W_b to determine the permanent work stations. If $W_f \leq W_b$ then make permanent FS station and vice versa. Complete this step is repeated until all the elements are allocated. Stop until FS = BS.

III. RESEARCH METHOD

The study began by literature study, accompanied by preliminary observations. Data were collected by interview, observation and literature study. The analysis method used is by using time study, forecasting, and line balancing are integrated with each other. Time data of each work element is found, then do the normality test, uniformity test and test the adequacy of using time study, then the data cycle time obtained is used to calculate the efficiency of production systems now with the method of line balancing, after it to make the proposal takes a new cycle in which this time can meet the demand, so do forecasting demand in advance using the methods of forecasting and can then be calculated the cycle time required. After the cycle time required is obtained then calculate the proposed system with line balancing method that consists of 3 methods: RPW, Moodie Young, and New Bidirectional. Afterwards, the best method is selected based on the results.

IV. RESULT AND DISCUSSION

A. Data Of Work Element Time

Preliminary data needed to perform the calculation of line balancing is to collect the data elements of the work and time of each element work. After observation there are 27 elements of work with 9 work stations for plastic bag production process. Data elements of work can be seen in TABLE I.

TABLE I. WORK STATION AND WORK ELEMENT

Work Stations	No	Work Element
A (Cord)	1	Fetch cord
	2	Measuring the length of the cord
	3	Cutting the cord
	4	Merger cord
	5	Combustion end of the cord
	6	Put the cord to a container
B (Cutting)	7	Put plastic roll to cutting manual
	8	Plastic Length Measurement
	9	The process of cutting manual plastic roll
	10	Put the plastic to container
C (Pressing)	11	Setting press machine
	12	Pressing the plastic
	13	Put the result of pressing into the container
D (Perforations)	14	Perforations plastic
E (Sewing)	15	Installation of the needle into the cord
	16	Sewing
	17	Put the sewing results to container
F (Installation of Cover Cord)	18	Fetch the ends of the rope
	19	Installation of the cover to the end of the cord
	20	Put the plastic into container
G (Folding)	21	Checking product
	22	Plastic folding
	23	Put the results folds into a container
H (Packaging)	24	Fetch packaging
	25	Insert plastic to the packaging
I (Sealing)	26	Setting heat sealer machine
	27	The process of sealing the packaging

B. Normality Test, Uniformity and Sampling Adequacy Test

Below are the results of the sampling adequacy test, normality test, and uniformity test of the data.

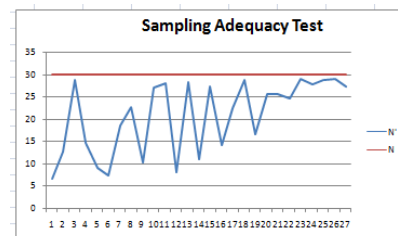


Fig. 2. Sampling Adequacy Test

In Fig. 2, data are adequate because $N' < N$.

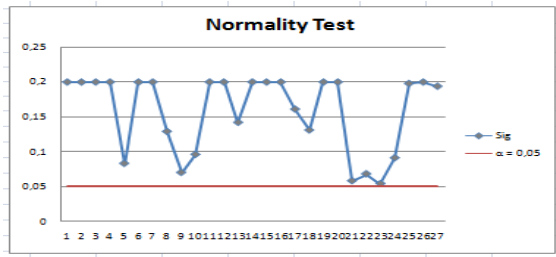


Fig. 3. Normality Test

In Fig. 3, $\text{sig} > \alpha$ then the data is a normal data.

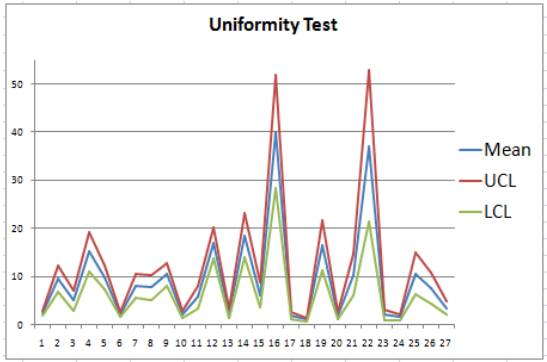


Fig. 4. Uniformity Test

In Fig. 4, $\text{UCL} > \text{Mean} > \text{LCL}$, then the data is uniform.

C. The Calculation of Standard Time

For the calculation of line balancing required standard time of each work elements. To calculate the standard time it takes the average cycle time, performance rating, the normal time and work allowance. Calculation of normal time using a performance rating of 8% and the computation time using the standard allowance of 14%. The results can be seen in the standard time column of TABLE II, TABLE III, and TABLE IV.

D. The Efficiency of Current Production System

Then, the cycle time calculation system is now calculated using total production of one year of data generated by the company which is 232.563 pieces, then divided by the number of days in the year (298 days) to obtain estimates of units produced per day. So total unit produced per day is $232,563/298 = 780.41$ pcs plastic bag/ day.

Calculation of the present production system cycle times are as follows:

Cycle time= 73.81 Second.

E. Forecasting Calculation

Forecasting calculation is needed to calculate the cycle time that needed. Trend analysis forecasting is used. From the forecasting result, production rate per day is $307,993/299 = 1030.07$ pcs. Then, we can calculate the cycle time that needed: $C = T/N = 57,600/1,030.07 = 55.92$ second.

F. Line Balancing RPW Result

Here in Table 2, is the result of weighting by using the method of RPW.

TABLE II. RPW RESULTS

Station	Element	Weight	Standard Time	Total Time (Second)
A	7	258.78	10.12	46.29
	8	258.78	9.85	
	9	248.93	13.23	
	10	235.70	2.74	
	1	233.59	3.00	
	11	232.96	7.35	
B	2	230.59	12.09	40.02
	12	225.61	21.46	
	3	218.50	6.48	
C	4	212.02	19.21	45.63
	13	204.15	3.11	
	14	201.04	23.31	
D	5	192.82	12.30	22.96
	6	180.52	2.79	
	15	177.73	7.87	
E	16	169.85	50.43	54.47
	17	119.43	2.54	
	18	116.88	1.49	
F	19	115.39	20.88	36.55
	20	94.51	2.54	
	21	91.97	13.13	
G	22	78.84	46.66	51.4
	23	32.18	2.67	
	24	29.51	2.07	
H	25	27.44	13.50	27.44
	26	13.94	9.55	
	27	4.38	4.38	

It can be seen in TABLE II that there are 8 work stations, the total allocated time of each work station can not exceed the cycle time which is 55.92 second.

G. Line Balancing Moodie Young Result

In addition RPW method, there is also Moodie Young. This method consists of two phases. TABLE III is the result of the Moodie Young method.

TABLE III. MOODIE YOUNG RESULT

Stations	Element	Standard Time	Total Time
A	7	10.12	43.29
	8	9.85	
	9	13.23	
	10	2.74	
	11	7.35	
B	1	3.00	55.86
	2	12.09	
	3	6.48	
	4	19.21	
	5	12.30	
	6	2.79	
C	12	21.46	55.75
	13	3.11	
	14	23.31	
	15	7.87	
D	16	50.43	54.47
	17	2.54	
	18	1.49	
E	19	20.88	36.55
	20	2.54	
	21	13.13	
F	22	46.66	51.40
	23	2.67	
	24	2.07	
G	25	13.50	27.44
	26	9.55	
	27	4.38	

TABLE III shows that there are 7 work stations, the total time of each work station can not exceed the cycle time which is 55.92 second.

H. Line Balancing New Bidirectional Result

One new method was developed to solve the problems of the balance of the new line is bidirectional; the method is based with the concept of critical path method.

Critical path is work elements that have slack value 0. From this experiment, work elements that have slack value 0 are work element 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27. New Bidirectional method results can be seen in TABLE IV.

TABLE IV. NEW BIDIRECTIONAL RESULT

Work Station	Work Element	Standard Time	Total Time (Second)
1 / FS ₁	7	10.1177	43.2879
	8	9.84558	
	9	13.2321	
	10	2.74186	
	11	7.3507	
2 / FS ₂	12	21.4577	55.7524
	13	3.1129	
	14	23.3079	
	15	7.87395	
3/FS ₃	16	50.4293	54.4674
	17	2.54413	
4/FS ₄	18	1.494	36.55
	19	20.88	
	20	2.54	
5/FS ₅	21	13.13	51.40
	22	46.66	
	23	2.67	
6/ FS ₇	24	2.07	55.857
	1	3.00066	
	2	12.0851	
	3	6.47581	
	4	19.2056	
	5	12.2982	
7/ BS ₁	6	2.79167	27.4387
	25	13.5013	
	26	9.55465	
	27	4.38279	

The work elements in permanent station from TABLE IV become work station. From the iteration, there are FS and BS. FS consist of work elements that is position in the critical path and BS consist of work elements that is position not in the critical path. And then the total time of FS (T(FS)) and BS (T(BS)) must not more than the cycle time that needed. T(FS) and T(BS) can be use to calculate the *slack time* of FS (W_f) and BS (W_b). If $W_f \leq W_b$, work station FS will be permanent and viseversa.

I. Line Balancing Method Comparison

TABLE V. LINE BALANCING COMPARISON

Indicator	Current	RPW	Moodie Young	New Bidirectional
Line Efficiency	48.89 %	72.60 %	82.97 %	82.97 %
Balance Delay	51.11 %	27.40 %	17.03 %	17.03 %
Smoothest Index	95.81	49.06	36.88	36.88
#Work Station	9	8	7	7

It can be clearly seen from TABLE V that when the company implemented Moodie Young or New Bidirectional method, the line efficiency will increase from 48.89% to 82.97%. The balance delay will be reduced from 51.11% to 17.03%. The number of work stations will be reduced from 9 stations to 7 stations, which means the number of labor required can also be reduced.

V. CONCLUSIONS AND RECOMMENDATION

A. Conclusions

1. Based on the line balancing method comparison, the best methods are Moodie Young method or New Bidirectional method. The two methods can increase the line efficiency from 48.89% to 82.97%, reduce the balance delay from 51.11% to 17.03%, and reduce the number of work stations from 9 work stations to 7 work stations.
2. Based on this research, it is possible to obtain a production target of 1,030.07 pieces of plastic bag per day. The time it takes to produce one piece of plastic bag is 55.92 seconds.

B. Recommendations for Future Research

In this study, researchers did not touch the aspects of the production layout. It is recommended for the company to conduct research on the production layout to further improve productivity and to enable better worker movement in the production facility.

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